DOCUMENT RESUME

ED 465 615 SE 066 337

AUTHOR	Matkins, Juanita Jo; Bell, Randy; Irving, Karen; McNall, Rebecca
TITLE	Impacts of Contextual and Explicit Instruction on Preservice Elementary Teachers' Understandings of the Nature of Science.
PUB DATE	2002-01-00
NOTE	27p.; In: Proceedings of the Annual International Conference of the Association for the Education of Teachers in Science (Charlotte, NC, January 10-13, 2002); see SE 066 324.
AVAILABLE FROM	For full text: http://aets.chem.pitt.edu.
PUB TYPE	Reports - Research (143) -- Speeches/Meeting Papers (150)
EDRS PRICE	MF01/PC02 Plus Postage.
DESCRIPTORS	Elementary Education; *Elementary School Teachers; Higher Education; *Methods Courses; *Preservice Teacher Education; Science Teachers; *Scientific Principles

ABSTRACT

Science educators have identified the development of accurate understandings of the nature of science as an instruction goal for nearly a century. Unfortunately, science instructors are unlikely to focus on the nature of science in content courses and the nature of science lessons are generally relegated to the methods courses where they are typically presented out of context as an add-on to the science curriculum. When addressed in this manner, preservice teachers may see the nature of science as supplemental, rather than integral to their science instruction. The purposes of this study were to assess the influence of instruction on a controversial science and technology based issue (global climate change and global warming (GCC/GW)) on elementary preservice teachers' understandings of the nature of science and the relative effectiveness of an explicit approach versus an implicit approach to the nature of science instruction. A matrix of the nature of science and GCC/GW instructional treatments were employed over a period of four semesters to elementary preservice teachers in a elementary science methods course (n=75). The findings determined that in the semesters where nature of science was taught explicitly, the posttest responses reflected current understanding at a substantially higher rate than those of the pretest. (Contains 26 references.) (MVL)

Reproductions supplied by EDRS are the best that can be made
from the original document.

IMPACTS OF CONTEXTUAL AND EXPLICIT INSTRUCTION ON PRESERVICE ELEMENTARY TEACHERS' UNDERSTANDINGS OF THE NATURE OF SCIENCE

ED 465 615

Juanita Jo Matkins, University of Virginia
Randy Bell, University of Virginia
Karen Irving, University of Virginia
Rebecca McNall, University of Virginia

PERMISSION TO REPRODUCE AND DISSEMINATE THIS MATERIAL HAS BEEN GRANTED BY
P. Rubba
TO THE EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)

Science educators have identified the development of accurate understandings of the nature of science as an instructional goal for nearly a century (Lederman, 1992). Despite the longevity of this instructional goal, research has consistently shown that K-16 students do not attain desired understandings (Duschl, 1990; Lederman, 1992, among others). One explanation for students' lack of success in learning current conceptions of the nature of science in K-12 classrooms is that the vast majority of elementary and secondary teachers rarely address this topic explicitly in their science instruction. Much of this failure is due to the lack of emphasis on the nature of science in the science courses of many teacher preparation programs. However, even programs emphasizing the nature of science as a theme have met with limited success in facilitating preservice teachers' abilities to understand and teach this elusive construct (Abd-El-Khalick, Bell, & Lederman, 1998; Akindehin, 1988; Author, 2000; Haukoos & Penick, 1983, 1985; Olstad, 1969; Scharmann & Harris, 1992). One possible explanation for the insufficiency of these programs is the uncontextualized manner in which they address the nature of science. With science instructors unlikely to focus on the nature of science in content courses, the nature of science lessons are generally relegated to the methods courses, where they are typically presented out of context as an add-on to the science curriculum (Driver, Leach, Millar, & Scott, 1996). When addressed in this manner, preservice teachers may see the nature of science as supplemental, rather than integral to their science instruction.

SE064337

U.S. DEPARTMENT OF EDUCATION
Office of Educational Research and Improvement
EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)
☐ This document has been reproduced as received from the person or organization originating it.
☐ Minor changes have been made to improve reproduction quality.
• Points of view or opinions stated in this document do not necessarily represent official OERI position or policy.

BEST COPY AVAILABLE

Current science and technology based issues such as global warming present the "messiness" of science-in-the-making and bring students into direct contact with the values, assumptions, and concepts embodying the nature of science. Furthermore, science and technology based issues situate lessons about science in the context of learning relevant science content. In many cases, these issues can be presented as subunits within a typical science methods course, eliminating the often-difficult task of finding science professors willing and able to tackle the nature of science in their content courses. Thus, many have argued that science and technology-based issues provide an ideal context for enhancing students' and teachers' understandings of the nature of science (Bentley & Fleury, 1998; Collins & Pinch 1998; Spector, Strong, & La Porta, 1998).

The Nature of Science

Although there is some disagreement regarding the specifics of the nature of science, there is an acceptable level of generality regarding the nature of science upon which the majority of experts agree and which is relevant and accessible to K-12 students (Lederman & Abd-El-Khalick, 1998; Smith, Lederman, Bell, McComas, & Clough, 1997). Included are the concepts that scientific knowledge is tentative (subject to change), empirically based (based on and/or derived from observations of the natural world), subjective (theory-laden), partly the product of human inference, imagination, and creativity (involves the invention of explanation), and socially and culturally embedded. Two additional aspects focus on the distinctions between observation and inference and the role and distinction of scientific theories and laws. This characterization of the nature of science is supported by current science education reform documents (American Association for the Advancement of Science, 1993; National Research Council, 1996), and it provided a conceptual framework in the present investigation. For a more

detailed description and justification of this characterization, see Lederman, Abd-El-Khalick, Bell, Schwartz, & Akerson (2001).

Method

Purposes

The purposes of this study were to assess (a) the influence of instruction on a controversial science and technology based issue (global climate change and global warming, or GCC/GW) on elementary preservice teachers' understandings of the nature of science, and (b) the relative effectiveness of an explicit approach versus an implicit approach to the nature of science instruction. To this end, a matrix of the nature of science and GCC/GW instructional treatments were employed over a period of four semesters (Table 1).

Table 1

Treatments by Semester

Semester	Treatment	# of Participants
Spring 2000	GCC/GW, explicit NOS	15
Fall 2000	No GCC/GW, implicit NOS	20
Spring 2001	No GCC/GW, explicit NOS	18
Fall 2001	GCC/GW, implicit NOS	22

Participants

The study involved all elementary preservice teachers enrolled in a required three-credit elementary science methods course at a major mid-Atlantic university. In total, the participants numbered 75 (70 females, 5 males), with ages ranging from 21 to 38 years. Most were fourth-year students enrolled in a 5-year BA/MT program. The majority (89%) were liberal arts majors,

with the other 11% majoring in science or mathematics. The MT program has a rigorous admissions policy focusing on GPA, GRE scores, and prior experience working with children. The consistent application of the MT admission criteria facilitated homogeneity of aptitude and achievement across treatment groups.

The Intervention

The controversial science issue selected for inclusion in the elementary science methods course was global climate change and global warming (GCC/GW). In the semesters when GCC/GW was taught, approximately 7 hours of class time were devoted to this instruction. Assignments included readings and discussion from popular periodicals and climatology literature, as well as hands-on inquiry activities related to GCC/GW (see Matkins & Bell, 2001 for a description of these activities). Additionally, environmental science faculty who were specialists in climatology met twice with the preservice teachers in small group settings to discuss current research findings and applications in the K-8 classroom.

Preservice teachers who received explicit nature of science instruction participated in a set of five inquiry-based activities taken from Lederman & Abd-El-Khalick (1998) and Lederman, Abd-El-Khalick, and Bell (2000) and a discussion of one reading assignment (Springston, 1997) selected to teach the seven target aspects of the nature of science. The preservice teachers participated in class discussions focusing on relevant nature of science aspects following each activity. Furthermore, in the nature of science with GCC/GW treatment group, the instructor encouraged the preservice teachers to relate characteristics of the nature of science to GCC/GW concepts as they were being taught.

Preservice teachers in the implicit nature of science instruction groups participated in none of the explicit nature of science activities in order to limit the potential source of changes in

their nature of science understandings to implicit sources (either the GCC/GW instruction and/or the inquiry-based methodology promoted by the elementary science methods course).

Data Collection

Data sources included pre- and post-questionnaires, interviews, relevant course assignments, and electronic journal entries. The nine-item open-ended questionnaire used to assess understandings of key elements of the nature of science and GCC/GW was based on the Views of Nature of Science questionnaire (Lederman et al., 2001). Five items focused on the previously mentioned aspects of the nature of science and four items related to GCC/GW. Following each administration of the questionnaire, six participants were interviewed to help establish validity of the questionnaire responses. Preservice teachers were purposefully selected for interviews to produce a stratified sample based on the available range of science backgrounds (from few to many secondary- and college-level science courses). During the audiotaped interviews, participants were asked to explain and elaborate on their responses to the questionnaires.

Data Analysis

In analyzing the data, the researchers have sought to provide rich descriptions of the beliefs of a limited number of participants based upon qualitative data, rather than less detailed treatment of a much larger sample. The descriptions will include excerpts from the preservice teachers' assignments, journal entries, questionnaire responses, and interview transcripts. It should also be noted that due to the participation of all students in the four semesters of the investigation and the inability to randomly select from among all preservice elementary teachers, it made most sense to treat the participants as the population, rather than a sample. What this approach loses in terms of generalizability, it gains in authenticity (generalization from such a

small, nonrandom sample makes little sense). Thus, this investigation may be seen as an initial attempt to frame the issues and as a foundation for future research.

The various data were first analyzed individually using Bogdan and Biklen's (1992) model of analytical induction and then together in order to test the validity of developing assertions. In this approach, working hypotheses to describe/explain the participants' views were continually formed and then tested against subsequent data. The ultimate goal was to develop generalized profiles for the preservice teachers' nature of science and GCC/GW understandings derived from systematic examination and re-examination of the available data. The variety of data sources permitted the triangulation of data and supported the validity of the profiles of each apprentice's understandings and apprenticeship experience. Finally, participants' profiles were compared to assess changes in the nature of science and GCC/GW understandings, and overall gains were compared among all treatment groups to assess the relative effectiveness of the four instructional approaches. Since two researchers analyzed the data, it was necessary to establish inter-rater agreement prior to the analysis of the entire data set. The researchers accomplished this through systematic comparison of separate analyses of three randomly selected data sets, with the end result of 90% agreement.

Results and Discussion

Results of the analyses of the preservice elementary teachers' responses to the questionnaire and follow-up interviews indicated significant pre- to posttest differences in their views of the nature of science and global climate change when those topics were explicitly addressed in the class. Overall, in the semesters where nature of science was taught explicitly, the posttest responses reflected current understandings at a substantially higher rate than those of the pretest (Table 2). Each data table is followed by a summary of pre and posttest responses and

by representative quotations. The coding system used in the following sections delineates whether specified data were collected prior to (Pre-) or after (Post-) and to identify individual participants (1 to 22). The concluding component of the coding system is the semester in which the individual was in the class (Spring/Fall, 2000/2001).

The Nature of Science

Pre-Instruction Views of the Nature of Science

The preservice teachers' pre-instruction responses reflected common misconceptions about the nature of science. For example, the majority viewed scientific knowledge as absolute truth. All participants believed that theories become scientific laws when proven true, and most were unable to explicate roles for imagination, creativity, or social influences in the development of scientific knowledge (see Table 2).

The Empirical Nature of Scientific Knowledge

The level of understanding of the empirical nature of science was consistently low across all semesters. Most of the participants were familiar with the use of evidence in science, and referred to scientists' use of observations and data. However, most also indicated that data and observations are the sole source of evidence, and that scientists use data and observations to *prove* their theories and conjectures. The roles of creative thought and the development of inferences in the establishment of scientific knowledge were not mentioned by most participants

> A scientific theory is an idea that has been tested and scientists are still testing to prove the theory as true.... A scientific law is a theory that has been tested and proven. (Pre-1, Spring 2000)

> I think that theories sometimes change. Using new technology scientists are able to find out more and more information regarding scientific theories. (Pre-6, Spring 2001).

Table 2

Percentage of Participants with Desired Views of Targeted Nature of Science Aspects

NOS Aspect	Spring 2000 Explicit GCC Explicit NOS (n = 15)		FALL 2000 Implicit GCC Implicit NOS (n = 20)		Spring 2001 Implicit GCC Explicit NOS (n = 18)		FALL 2001 Explicit GCC Implicit NOS (n = 22)	
	Pre%	Post%	Pre%	Post%	Pre%	Post%	Pre%	Post%
Empirical nature of scientific knowledge	27	73	0	0	17	68	9	9
Tentative nature of scientific knowledge	0	60	0	5	6	56	5	9
Role of creativity	0	67	0	0	6	67	0	5
Subjective nature of scientific knowledge	20	80	0	5	17	67	32	23
Social & cultural influences	0	27	0	0	0	0	0	0
Observation vs. inference	27	67	0	0	6	56	14	14
Theories vs. law	0	80	0	0	0	78	0	0

The Tentative Nature of Scientific Knowledge

Consistent with the belief that a goal of scientists is to prove their ideas, participants viewed theories as weakly supported ideas that were easily and often revised. This misconception about the tentativeness of science as it related to scientific theories was common across semesters. In addition, participants consistently discussed scientific laws as aspects of scientific knowledge that were proven. Thus, the absolutist beliefs of the participants at the

beginning of each semester were in contradiction to the common tenet in the scientific community of the tentativeness of scientific knowledge.

> Scientific theory has not stood the test of time or cannot be proven correct 100% of the time, such as the theory of evolution. Laws of science cannot be broken. (Pre-10, Spring 2001)

> A great example of [theory change] is the always-baffling unanswered question of how to lose weight. At least hundreds, if not thousands, of theories exist on this topic, many of which contradict one another and confuse the public. (Pre-2, Spring 2000)

The majority saw scientific laws as proven beyond a shadow of doubt. For these preservice teachers, scientific laws, along with facts and observations, constituted absolute knowledge that would never change. These participants also expressed the misconception of a hierarchical relationship between scientific theories and laws.

> A law is a theory that has been proven beyond a reasonable doubt. (Pre-22, Fall 2001)

> A scientific theory cannot necessarily be proven, whereas a law is believed to be a constant, accurate explanation of something in the science world that has been tested and re-tested. A theory is usually the first step in constructing, or formulating, a law. (Pre-9, Spring 2000)

Most participants linked the tentativeness of scientific theories to the empirical nature of science. In fact, the collection of new data and the accumulation of counter evidence were typically cited as the sole source of change. None of the participants mentioned the possibility that scientific theories could change due to new insight or new ways of looking at existing data.

The Role of Creativity in Constructing Scientific Knowledge

Although most participants expressed the belief that science involved creativity, particularly in "designing experiments" and to "create ideas to be tested", no one talked about the creativity of data interpretation. Several participants cited the "scientific method" as the regimen through which science progresses, a view that is at odds with science as a creative endeavor.

Prior to instruction, most of these preservice teachers viewed creativity as playing a role only before the real science (i.e., scientific method) is applied.

> Science and art are similar because in both genres you have to be creative and willing to experiment. Scientists have to create ideas to be tested while artists create how they want to portray an idea. Both fields follow methods, need materials, and experiment. (Pre-2, Spring 2001)

> Science has a method, but it is the scientists who expand this method, who work outside of the box, that are considered brilliant and ingenious scientists. (Pre-14, Spring 2000)

The Subjective Nature of Scientific Knowledge

The preservice teachers described a degree of subjectivity as inherent to the construction of scientific knowledge. Most participants spoke of subjectivity only in a general way, such as differences in "data interpretation": "There can be different interpretations of the data based on their knowledge." (Pre-22, Fall 2001). A few of the participants' pre-instructional responses described subjectivity in the negative sense that "…sometimes people 'see' simply what they want to believe" (Pre-6, Spring 2000).

Cultural Influences on Scientific Knowledge

None of the participants made any reference to cultural influences on the scientific enterprise in their pre-instructional responses to the questionnaire and follow-up interviews.

Post-Instruction Views of the Nature of Science

Substantial changes in participants' nature of science views were realized only in the post-instruction responses of the participants in the two explicit nature of science treatment groups (Table 2). In general, these responses reflected less commitment to absolute views of science and greater understandings of human factors contributing to the tentative nature of scientific knowledge. These results add further support to the growing body of literature

supporting an explicit approach to the nature of science instruction (Akerson, Abd-El-Khalick, Lederman, 2000; Bell, Blair, Lederman, & Crawford, 1999; Shapiro, 1996).

The Empirical Nature of Scientific Knowledge

In the semesters that involved explicit instruction in the nature of science, the participants' post-instructional views differed in that a high percentage (73% and 68%) realized that scientists often go beyond the observable when constructing scientific ideas and theories.

> Different scientists look at the same topic in different lights drawing from their own theories, backgrounds, and research. While they have the same data, these factors lead them in different directions and approaches to the topic. (Post-12, Spring 2000)

> Every scientist comes to his work with a different set of experiences and pre-conceived notions. Just as two people can look at the same drawing/read the same poem and see/hear different things, so too can two scientists deduce different information. (Post-6, Spring 2001)

Whereas references to "proving" scientific ideas as "true" were common in the pre-instruction responses, the same ideas were largely absent from the post-instructional responses in the groups who received explicit instruction in nature of science. In the groups who received no explicit nature of science instruction, there was no change in the very small percentage of students who recognized the usefulness of various perspectives in the development of scientific knowledge.

The Tentative Nature of Scientific Knowledge

In the groups that received explicit nature of science instruction, post-instructional responses indicated important shifts in the participants' largely absolute views of scientific knowledge. While all participants continued to express the belief that theories change because of new evidence, several also described theory change as a result of new ways of looking at existing evidence.

> I think theories change....The theories about dinosaur extinction have changed because of new evidence and a new perspective on data. (Post-1, Spring 2000)

> Since theories are founded on interpretations of observations, different scientists may propose different theories despite potential use of the same set of data. (Post-11, Spring 2000)

All of the participants who received explicit nature of science instruction also spoke of the explanatory function of theories, something that was entirely lacking in their pre-instructional responses. In fact, in a majority of the post-instructional responses, participants contrasted theories and laws by their function, rather than level of "proof." Some referred specifically to nature of science activities in which they participated in their class.

> A scientific theory explains why something is happening. A scientific law is a summary of observations. It is a generalization ... it explains why something is happening. In the tube experiment, we made a law that said that no matter which string we pull, the longer one goes in. This is a summary of all our observations. (Post-18, Spring 2001)

> A scientific theory is an explanation of why something happens. A law is a summary of observations – it is a generalization about a phenomenon that is explained by a theory. (Post-2, Spring 2001)

Post-instructional responses in the two explicit nature of science groups also tended to contrast theories and laws by the types of knowledge from which they are derived. The participants clearly saw theories as inferential in nature and scientific laws as generalizations. This contrasted markedly with their pre-instruction misconception that laws are of the same type of knowledge and are, in fact, derived from theories.

In the two groups who received no explicit nature of science instruction there was no change in the responses about the tentativeness of science in the post-instruction data set.

The Role of Creativity in Science

In both semesters in which explicit nature of science instruction was employed, about 67% of the participants expressed adequate post-instructional views of the role of imagination and creativity in the generation of scientific knowledge. According to the participants in these two semesters of the course, creativity permeates the scientific process in both the design of experiments and in the interpretation of data. Most agreed that "creativity drives both scientists and artists" (Post-2, Spring 2000). The change in participants' views was further emphasized by their rejection of the conception of a single scientific method. Contrary to their prior beliefs, they allowed for many methods and creative approaches to the process of generating scientific knowledge.

> Not everything can follow the scientific method—like, if you're trying to find out about dinosaurs….I don't think that every time someone is going to state a hypothesis before they discover something. (Post-1, Spring 2000)

In the groups that received no explicit nature of science instruction, the percentage of students who expressed understanding of the creative processes in science was consistently negligible.

The Subjective Nature of Scientific Knowledge

The view that science is completely rational and objective was rejected by 80% and 67% of the participants in the explicit nature of science groups, in their responses to Item 5 of the posttest. Rather, they described how scientists' backgrounds, personal views, and biases toward the data potentially played a role in their interpretation of the data. Contrary to their pre-instructional responses, none of the participants cast subjectivity in a totally negative light.

> It is possible that different people make different inferences from the same data and observations. (Post-17, Spring 2001)

Different conclusions are the result of different interpretations of data. Scientists draw varying inferences based on unique personal experiences, backgrounds, and systems of thought and belief. Every individual is the product of a unique set of life experiences, program of study, and mindset. All of these factors affect how a researcher interprets a given set of data. (Post-11, Spring 2000)

Students who did not receive explicit nature of science instruction persisted in their general statements about why scientists might differ in their beliefs. None cited different interpretations of the data as a reason, and several continued to characterize differences in science as the result of personal bias and prejudice on the part of scientists. Even the group that received explicit GCC/GW instruction showed no gains in understanding the role of inference, interpretation, and theory development in science.

Cultural Influences on Scientific Knowledge

In contrast to the pre-instructional responses, in which the participants made no reference to cultural influences, 4 of the 15 participants (27%) in the group receiving BOTH nature of science and GCC/GW instruction described how cultural influences could affect the scientific enterprise and the knowledge it constructs. Three of these references to cultural influences described how the culture at large could affect what science is done and how it is received.

> [Without teaching theories] we would not see, for example, that the Copernican model that the earth revolved around the sun was widely unaccepted during his time because it rejected the Christian idea that the Earth is at the center of the universe and everything revolved around it. (Post-12, Spring 2000)

In the other three groups there was no gain in understanding the impact of the culture upon the scientific enterprise. This was the only aspect of NOS in which the second NOS group, the one which received no GCC/GW instruction, made no gains.

Global Climate Change/Global Warming

Pre-Instruction Views of Global Climate Change and the Nature of Science

In all semesters of the project, a large majority of the preservice teachers held pre-instruction misconceptions about GCC/GW. These included beliefs that the greenhouse effect is both unnatural and (always) harmful, that scientists as a group believe the same thing about GCC/GW, and that the greenhouse effect is either a scientific theory, because it is unproven, or a scientific law because it is proven.

In the pre-instruction questionnaires and interviews in all semesters, student responses ranged from statements about GCC/GW that contained multiple misconceptions to responses that used some correct descriptions and terminology. The ideas found in the following examples were commonly expressed in all semesters in the pre-instruction responses. Many students believed that the ozone hole was the primary causal factor in the greenhouse effect, that the greenhouse effect and global warming were synonymous, and that the greenhouse effect worked by trapping heat or gasses in the atmosphere.

> It [the greenhouse effect] is caused by a hole in the ozone layer which allows stronger sun rays in. The heat of the sun is slowly heating the temperature of the earth causing the polar caps to begin melting. This increases the amount of water in the ocean and leads to erosion on the shores and loss of land. (Pre-2, Spring 2000)

> The greenhouse effect is the gradual loss of the protective ozone layer due primarily to the release of certain man-made gasses. The loss of the filter is allowing more of the sun's rays to pass through the atmosphere causing a general warming of the Earth's surface. (Pre-2, Fall 2001)

In a few instances, students expressed correct understandings of the greenhouse effect and its mechanisms. Even these students expressed other misconceptions, such as characterizing the effect as a trapping of energy in the atmosphere, listing isotopes as greenhouse gases (C_{14}), naming gases that did not occur naturally prior to the 20th century (CFC's, first synthesized in

Table 3

Percentage of Participants with Desired Views of Targeted GCC/GW Aspects

Response Categories	Spring 2000 Explicit GCC Explicit NOS (n = 15)		FALL 2000 Implicit GCC Implicit NOS (n = 20)		Spring 2001 Implicit GCC Explicit NOS (n = 18)		FALL 2001 Explicit GCC Implicit NOS (n = 22)	
	Pre%	Post%	Pre%	Post%	Pre%	Post%	Pre%	Post%
Greenhouse effect (GE) is natural & mostly beneficial	26	67	15	30	6	6	5	73
Correct understanding of theory or law, connected with greenhouse effect	7	73	10	5	17	67	0	0
Scientists are characterized as individuals	40	73	35	45	22	50	27	27
Support for government energy policies	73	100	80	85	61	67	82	68
Informed conditional support for government energy policies.	0	67	5	5	0	0	0	5

1928), and failing to distinguish between particles and gases. Even the most correct descriptions were not correct to a level that one could reasonably expect any of the respondents to accurately teach the concepts to children. The following excerpts from student responses were the most correct pre-instruction responses from two class sets.

> Certain particles, CFCs, $C_{14,}$ and others form a blanket in the stratosphere that "insulates" the earth—keeps the earth warm by keeping heat emitted from the sun around the earth. (Pre-1, Spring 2000)

> Radiation from the sun enters into the earth's atmosphere and it is both absorbed by the earth and reflected by it. Part of the light and heat energy that is reflected gets trapped by the atmosphere and warms the earth.(Pre-15, Spring 2001)

Across semesters, participants' pre-instruction explanations about whether the greenhouse effect is a theory or a law reflected conventional understandings about theories as unproven conjecture and laws as proven. This was consistent across groups.

> If it were a law, it is probable that results/consequences of the phenomena would have to have been observed and recorded a number of times (it would become provable and a fixed phenomena). (Pre-9, Spring 2000).

> Theory. Since there is a difference of opinion on why the earth is warming, the greenhouse effect is only a theory. If someone could prove that the greenhouse effect explains the earth's warming 100% of the time, then it could be a law. (Pre-12, Fall 2000)

Another characteristic student belief was the uniformity of opinion about global warming in the scientific community. Most responses contained references to scientists as a single-minded group whose beliefs were expressed as one unit. This response corresponded to their pre-instruction beliefs about the subjectivity of science, and was consistent with their absolutist views of science.

> Scientists are certain that there is a hole in the ozone layer that continues to expand. Scientists are uncertain about the rate at which it is expanding, nor do scientists know for sure how grave the danger of increasing temperatures is. They only know that the Earth in general is warming up. (Pre-5, Spring 2001)

> Scientists are about 75% sure that the Earth is warming at a dangerous rate. They are trying to increase awareness about pollution and the depletion of the ozone to slow the warming of the Earth. (Pre-9, Fall 2001)

Consistent with the responses of the majority of the participants each semester that scientists were in agreement about global warming, over 60% each semester indicated willingness to support the development of alternative energy sources even if the actions taken raised their taxes or cost them in other ways. Pre-instruction data showed only one example in all

semesters of application of knowledge of the nature of science and/or of GCC/GW in response to this question.

> Yes. I'm pretty convinced that emission reduction would perhaps slow down, if anything, this perceived effect. The problem is expense, of course, but I, personally, would support such a program. (Pre-10, Fall 2000)

The previous response contrasted with the prevalent sentiment expressed. Most students supported taxation for the proposed government program with reasoning that lacked critical consideration of the nature of science or the issue of global warming.

> Yes - anything to help save our Earth would be worth it. Eventually, they would hopefully be able to get the prices down. (Pre-18, Spring 2001)

> Yes!!! (Pre-17, Fall 2001)

Post-Instruction Views of Global Climate Change and the Nature of Science

As expected, only in the explicit GCC/GW groups did participants demonstrate substantial post-instruction gains in GCC/GW understandings. Though not every participant in the explicit GCC/GW groups moved to correct and complete understandings, a large portion of each class did (Table 3). Also, most participants were willing to support government action to encourage the use of alternative energy sources. The following sections highlight the changes in participant understandings of global climate change and the nature of science as it intersected with the study of global climate change.

At the end of the explicit GCC/GW semesters many more students held the correct understanding of the greenhouse effect, in contrast to very few at the beginning of the semester. The understandings expressed in their posttest questionnaires were generally more thorough and showed a deeper understanding of the processes involved in the greenhouse effect. Some respondents made a direct connection between the nature of models and the greenhouse effect as

a model. Given that most participants were confused about the greenhouse effect at the beginning of the study, the thoroughness and clarity of posttest responses is especially notable.

> The greenhouse effect is a proposed explanation for increased Earth temperatures. It is not the same as "global warming," and often receives a negative connotation. The greenhouse effect is a model, much like a real greenhouse, that reflects gases held to the Earth by gravity that in turn insulates the earth's surface because of a loss of energy – we probably couldn't live on earth without some degree of greenhouse effect. (Post-9, Spring 2000)

> It is the net warming of the earth because some of the sun's energy is absorbed by the earth and then re-emitted and absorbed in the atmosphere. But some of the sun's energy escapes back into space. It does not cause "global warming," it is actually the phenomenon that allows the earth to be at this temperature. Otherwise temperatures would drop below 0 . (Post-20, Fall 2001).

Only in the explicit NOS instruction semesters did students' post-instruction responses indicate that a majority of the students understood that scientists are individuals and have various opinions about GCC/GW. In the semester where students received explicit instruction in both GCC/GW and NOS, 80% of the students in the class learned that scientists differ in their ideas about whether or not global warming is happening at a dangerous rate, as compared to 53% on the pretest. In the posttest responses, participants expressed an understanding of the function of inference in the development of scientists' ideas about global warming.

> Some scientists are certain that the Earth is warming at a dangerous rate. Some scientists are certain that the Earth is cooling, while others are certain it is all part of a cycle. They are all inferring different things based on the same data. (Post-4, Spring 2000)

In the other semester that included explicit NOS instruction, responses reflecting the individuality of scientists more than doubled in pre- to post- responses. For example, "I would say some scientists are certain while others aren't. " (Post-5, Spring 2001). Despite explicit reading assignments and meetings with research scientists, the explicit GCC/GW groups that did

not receive explicit NOS instruction showed very little gain in understanding of the subjectivity of science as exemplified in the debate in the scientific community over global warming.

> I do not think they are very certain. They are just trying to follow the calculations that they have figured out. (Post-8, Fall 2001)

Prior to instruction, most participants in all semesters of the project based their choice of "theory" or "law" to characterize the greenhouse effect upon whether or not they believed the greenhouse effect was proven or not. Participation in the science methods course without NOS instruction did not result in gains in correct understandings of scientific theories and laws. GCC/GW instruction did not lead to gains in this area of nature of science understanding. In contrast, after instruction in the two explicit NOS semesters, about 70% of the participants responded to the question with correct explanations about theories and laws, and all 70% referred to the nature of the reasoning as the justification for their answer. Furthermore, they used the science process nomenclature of observation and inference, as they had been taught in the course, to clarify their reasoning.

> The greenhouse effect is a law—if it is described as the reflective effect of the atmospheric gases on radiant energy. If, however, it is described as being the effect of changes in atmospheric composition on global climate change, it is a theory. Laws are based on strict observations while theories are founded on inferences, which involve the interpretation of observations. (Post-11, Spring 2000)

> If it's based on observations – such as records of relative amounts of gas in a sample of the atmosphere – it's a law. If it's based on inferences – such as an explanation about why the Earth's temperature is rising – it's a theory. I think it's probably a theory because it's a possible explanation of why temperatures are rising. (Post-13, Spring 2001)

With the exception of one semester group, there was no notable change across semesters in the willingness to commit to paying for a government program to develop alternative energy courses. The group that received explicit NOS and GCC/GW instruction was the only group to

show an overall shift to the use of explanations about their choices consistent with knowledge of NOS and GCC/GW (Table 3). In addition, this was the only semester in which many students explained their willingness in a manner that showed both their understanding of the GCC/GW issue and of the nature of science.

> If consensus within a majority of the scientific community were reached about the earth warming at a potentially detrimental rate, yes I would support the move to more costly alternative energy sources. (Post-1, Spring 2000.)

Even without GCC/GW instruction, the group receiving explicit NOS instruction developed better understandings of theories and laws and appeared able to apply these understandings to the topic of GCC/GW (Table 3). However, these participants' responses to the GCC/GW questions on the post-questionnaires showed no improvements in the application of the NOS topic to understandings of other NOS aspects, such as viewing scientists as individuals.

Discussion

Preservice elementary teachers in these groups made substantial gains in understandings of the NOS when instructed explicitly in aspects of NOS in conjunction with instruction in a controversial science issue, GCC/GW. These participants also made substantial gains in NOS with explicit NOS instruction and *no* instruction in GCC/GW. Explicit instruction in NOS appears to benefit student understandings of NOS whether or not it is combined with a controversial science topic, though the effect was greater when NOS and GCC/GW were both taught explicitly. Likewise, when no explicit instruction in NOS occurred, no gains were seen in NOS understandings.

Interestingly, most of the participants, all semesters, *believed* they had learned about the nature of science whether or not the topic was addressed explicitly in the methods course. This belief is contrary to the data for the implicit nature of science groups, whose understandings

showed little change from pre- to posttest administrations of the questionnaire. However, given their responses to specific probing during the interviews, it appears that these preservice teachers conflated nature of science with science process skills, a topic that was addressed extensively in their methods course. This conflation has been reported in previous studies involving preservice teachers (Abd-El-Khalick et al., 1998; Bell, Lederman, & Abd-El-Khalick, 2000), and serves as a reminder that it is easy for methods students to confuse the method with the message, especially when an implicit approach is used.

The only gain in the explicit global climate change/implicit nature of science group was in the understandings about the definition of the greenhouse effect. Also, in the explicit NOS groups, gains were seen in the ability to connect the correct meaning of scientific laws and theories to the greenhouse effect, regardless of GCC/GW instruction. Therefore, it appears that in-depth, student-centered coverage of a controversial issue is not enough to improve participants' views of NOS. However, accompanying NOS instruction with investigations of a real-world topic that illustrates the NOS aspects and enables application of those aspects appears to be more beneficial than either approach alone.

The results of this investigation strongly support the necessity of an explicit approach to nature of science instruction (Bell, et al., 2000; Shapiro, 1996; Bell, Blair, Lederman, & Crawford, 1999). Instructional activities consistent with currently accepted ideas of NOS (e.g., footprints activity, science process skills activities, discussions of controversial topics) were employed in all iterations of this investigation, but were not enough. The specific aspects of the scientific enterprise that characterize the nature of science should be addressed specifically in instruction.

Although further research is needed before generalizing these results to other situations, this investigation provides support for an explicit, context-based approach to nature of science instruction in the elementary science methods course. While explicit nature of science instruction situated in the context of science controversy produced the greatest gains in nature of science understandings, explicit nature of science instruction alone was nearly as effective. Science methods instructors whose time constraints preclude including detailed instruction on science content or on a particular science controversy may see gains in their students' nature of science understandings through the less-time intensive explicit approach alone.

Future investigations will need to further assess nature of science instruction situated within and without science controversies (e.g., genetic manipulation, cloning, nuclear energy, and evolution) in order to explore the generalizability of the findings reported here. It is also important before generalization that other group situations be investigated; secondary or inservice teachers may respond differently to NOS instruction combined with GCC/GW. Also, it is important to extend this line of research longitudinally to address the critical question of whether elementary preservice teachers are able to translate their nature of science understandings into classroom instruction.

In the end of the semester interviews with participants who experienced explicit nature of science instruction, we asked whether this project would influence their future teaching. Their comments indicated intent to incorporate these understandings into their teaching, as illustrated in the following comment:

> [Studying GCC/GW and the nature of science] makes you realize that science isn't always exact and so you have a responsibility to teach both sides and all angles of a scientific issue. (Post-1, Spring 2000)

We believe the approach of explicit nature of science instruction has great potential for developing elementary teachers with complete understandings of the nature of science, and that adding in science content such as global climate change/global warming strengthens the understandings of the participants. Not only do the participants gain understanding, but science also becomes more accessible and relevant. As the participant quoted above remarked while packing up her bookbag after the interview:

> It makes me want to go back and re-evaluate what I thought I knew and ask more questions. Like, it kind of awakens the scientist inside me . . . (Post-1, Spring 2000)

References

Abd-El-Khalick, F., Bell, R.L., & Lederman, N.G. (1998). The nature of science and instructional practice: Making the unnatural natural. *Science Education, 82*, 417-436.

Akerson, V. L., Abd-El-Khalick, F., Lederman, N. G. (2000). Influence of a reflective explicit activity-based approach on elementary teachers' conceptions of nature of science. *Journal of Research in Science Teaching, 37*, 295-317.

Akindehin, F. (1988). Effect of an instructional package on preservice science teachers' understanding of the nature of science and acquisition of science-related attitudes. *Science Education, 72*, 73-82.

American Association for the Advancement of Science. (1993*). Benchmarks for science literacy: A project 2061 report*. New York: Oxford University Press.

Bell, R. L., Blair, L. M., Lederman, N. G., & Crawford, B. A. (1999). Just do it? The effect of a science apprenticeship program on high school students' understanding of the nature of science and scientific inquiry. In P. Rubba, J. Rye, & P. Keig (Ed.), *Proceedings of the 1999 Annual International Conference of the Association for the Education of Teachers in Science*. Pensacola, FL: Association for the Education of Teachers in Science.

Bell, R. L., Lederman, N. G., & Abd-El-Khalick, F. (2000). Developing and acting upon one's conception of the nature of science: A follow-up study. *Journal of Research in Science Teaching, 37*, 563-581.

Bentley, M. L. & Fleury, S. C. (1998). Of starting points and destinations: teacher education and the nature of science. In W. F. Mccomas (Ed.), *The nature of science in science education: Rationales and strategies*. Kluwer Academic Publishers, Boston, 277-291.

Bogdan, R.C., & Biklen, S.K. (1992). *Qualitative research for education: An introduction to theory and methods*. Boston: Allyn and Bacon.

Brown, J. S., Collins, A., & Duguid, P. (1989). Situated cognition and the culture of learning. *Educational Researcher, 17*, 32-42.

Collins, H.M. & Pinch, T. (1998) *The golem: What you should know about science*. (2nd ed.). Cambridge, MA: Cambridge University Press.

Driver, R., Leach, J., Millar, R., & Scott, P. (1996). *Young people's images of science*. Philadelphia: Open University Press.

Duschl, R.A. (1990). *Restructuring science education*. New York: Teachers College Press.

Haukoos, G. D., & Penick, J. E. (1983). The influence of classroom climate on science process and content achievement of community college students. *Journal of Research in Science Teaching, 20*, 629-637.

Haukoos, G. D., & Penick, J. E. (1985). The effects of classroom climate on college science students: A replication study. Journal of Research in Science Teaching, 22, 163-168.

Lederman, N. G. (1992). Students' and teachers' conceptions of the nature of science: A review of the research. *Journal of Research in Science Teaching, 29*, 331-359.

Lederman, N. & Abd-El-Khalick, F. (1998). Avoiding de-natured science: Activities that promote understandings of the nature of science. In W. F. McComas (ed.), *The nature of science in science education: Rationales and strategies*. Kluwer Academic Publishers, Boston, 83-126.

Lederman, N. G., Abd-El-Khalick, F., & Bell, R. L. (2000). If we want to talk the talk we must also walk the walk: The nature of science, professional development, and educational reform. In J. Rhoton and P.S. Bowers (Eds.), *Issues in science education: Professional development planning and design*. Arlington, VA: National Science Teachers Association.

Lederman, N.L., Abd-El-Khalick, F. S., Bell, R. L., Schwartz, R., & Akerson, V. L. (2001). *Assessing the "un-assessable": Views of nature of science questionnaire (VNOS)*. A paper presented at the Annual Meeting of the National Association for Research in Science Teaching, St. Louis, MO.

Matkins, J. J., & Bell, R. L. (2001). Awakening the scientist inside: Global climate change and the nature of science in an elementary science methods course. In P. Rubba, J. Rye, W. Di Biase, & B. Crawford (Ed.), *Proceedings of the 2001 Annual International Conference of the Association for the Education of Teachers in Science*. Pensacola, FL: Association for the Education of Teachers in Science.

National Research Council. (1996). *National science education standards*. Washington, DC: National Academic Press.

Olstad, R. G. (1969). The Effect of science teaching methods on the understanding of science. *Science Education, 53*, 9-11.

Scharmann, L. C., & Harris, W. M., Jr. (1992). Teaching evolution: Understanding and applying the nature of science. *Journal of Research in Science Teaching, 29*, 375-388.

Shapiro, B. L. (1996). A case study of change in elementary student teacher thinking during an independent investigation in science: Learning about the "face of science that does not yet know." *Science Education, 80*, 535-560.

Smith, M. U, Lederman, N. G., Bell, R. L., McComas, W. F., & Clough, M. P. (1997). How great is the disagreement about the nature of science? A response to Alters. *Journal of Research in Science Teaching, 34*, 1101-1104.

Spector, B., Strong, P. & LaPorta, T. (1998). Teaching the nature of science as an element of science, technology and society. In W. F. McComas (ed.), *The nature of science in science education: Rationales and strategies*. Kluwer Academic Publishers, Boston, 267-276.

Springston, R. (1997, April 24). Theory: Taming a wild guess. *The Richmond Times Dispatch*, pp. C1, C4.